REGRET THEORY AND THE PROVISION OF BINARY PUBLIC GOODS. EXPERIMENTAL ANALYSIS*

Josefa Tomás

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Correspondence: University of Alicante. Facultad de Ciencias Económicas.

Depto. de Fund. del Análisis Económico. Ctra. San Vicente del Raspeig, s/n.

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A B S T R A C T

This paper analyzes the provision of discrete public goods when individuals exhibit regret/rejoicing in their preferences. The problem is studied using Regret Theory as opposed to the Bayesian approach. This model is shown to be supported by existing experimental data on binary voluntary contribution games.

Keywords: Binary Public Goods; Bayesian Equilibrium; Regret Theory.

1 INTRODUCTION

It has been established in economic theory that members of a group tend to behave as "free riders" when they are asked to provide funds in order to produce a common good. However, if they all decide not to take part in the project, it cannot be carried out, and all members of the group are negatively affected as a consequence. This conflict is at the origin of the so-called public goods' provision problems[1].

An interesting case, which has been given considerable attention, is the one involving a contribution threshold or a provision point, necessary for the provision of the project. In this case the public good is produced only when a certain amount of money, work or resources has been handed over. On the other hand, the quality or quantity of the provision does not increase even when contributions exceed the provision point. These goods are known in the literature as "lumpy", "binary", "discrete" or "pure step" goods, and examples of them include bridges, railway tracks, roads, public radio and television, etc. The free-rider problem is still present in this case, since each member of the group benefits when it is possible to reach the level required to produce the common project without his/her contribution[2].

In these kind of problems, agents have no information about the relevant characteristics of the other members of the group –degree of generosity, altruism etc.– which may influence their behaviour. In this context, Rapoport (1985) introduced the notion of uncertain strategies, which take into account each individual's opinion about whether or not the number of contributing members will suffice to reach the good's provision point.

Palfrey and Rosenthal (1991) model this kind of uncertainty by associating it with the individual's assessment of his/her provision of the public good. In their model, each individual is given a unit of the good (his/her endowment), each individual's assessment of this unit is private information. The probability distribution of the

[1]Relevant papers for our purposes include Groves & Ledyard (1977); Marwell & Ames (1979, 1980, 1981); Kim & Walker (1984); Isaac, Walker & Thomas (1984) and Ledyard (1995).

[2]Some of the most relevant approaches about the provision of this particular kind of public goods are those of Palfrey & Rosenthal (1984, 1988, 1991) and Rapoport & Suleiman (1992, 1993).

assessments is common knowledge, though. Behaviour is reduced to a simple binary decision: Whether to contribute or not his/her endowment to the production of the public good. In order to maximize their objectives, agents form beliefs regarding the other players' probable behaviour, and make a corresponding decision.

This model intents to test in the laboratory the Nash Bayesian equilibrium predictions proposed in game theory as solutions to these kind of problems. The main result they obtain from a total of 33 experiments is that the Nash Bayesian equilibrium theory fits the aggregate empirical results fairly well, but it does not explain individual behaviour correctly. They propose a behavioral hypothesis in order to explain the observed deviations from Nash Bayesian equilibrium predictions. The idea is that individuals are Bayesian, but they overestimate the probability that the rest of the people will contribute (Hypothesis H). This hypothesis makes predictions about the direction of the deviations from Nash Bayesian equilibrium. They also prove that these deviations cannot be explained adding risk aversion or using cooperative game theory, or psychological theories such as Kahneman and Tversky's Prospect Theory (1979), where the utility function shows both risk-aversion and risk-acceptance.

In this paper we analyse the problem of provision of binary public goods by applying Loomes and Sugden's Regret Theory (1982, 1987). In fact, the problem of whether or not to contribute to the provision of a public good may involve a certain level of satisfaction or regret, depending on the decision made to collaborate or not. This might happen, especially when the size of the group is small, as it is the case of the experiments. As it will be shown below, this model explains the experimental results better, in general, than the one of Palfrey and Rosenthal does, without making use the much critiziced assumption of expected utility maximization. In particular, if we assume the hypothesis of biased probability within our model, we are able to predict the correct direction of the deviations observed, as Palfrey and Rosenthal's model does.

In section 2 we develop Palfrey and Rosenthal's theoretical model and analyze the consequences arising from the introduction of the hypothesis of biased beliefs. Section 3 is devoted to the analysis of the problem according to the regret model. In section 4 we make a comparative study of the aforementioned theories, the Bayesian model, adding Hypothesis H, and Regret Theory for which we also analyse the effect of Hypothesis H. Finally section 5 concludes the paper.

2 THE EQUILIBRIUM MODEL OF VOLUNTARY CONTRIBUTIONS OF PALFREY AND ROSENTHAL.

The model of voluntary contributions is a game where the N players move simultaneously in order to choose between two possible strategies i.e. *to contribute or not to contribute.* In fact, each member of the group is given an indivisible unit which he/she can either assign to the common project (contribute) or consume (not to contribute). The common project requires at least w units of input, i.e. it needs at least w individuals to contribute in order to be carried out. Each individual valuates his/her unit of the good (his/her endowment) differently, this valuation is private information. The rest of the group members only know that these valuations obey a known probability distribution.

The private value of each endowment will be denoted by c_i. This value can be understood as *each individual's contribution cost* because the higher the valuation, the harder it is for the individual to give it up for the common project. It is assumed that the common value of the public good is normalized equal to one, and that the cumulative probability distribution $F(\cdot)$, used for endowments valuations, is continuous and strictly increasing on $[0, \overline{c}]$ with $\overline{c} > 0$. Then $F(0) = 0$ and $F(\overline{c}) = 1$. Payoffs to player i, with a contribution cost $c_i = c$ are given by[3]:

1. 1+c when i does not contribute and at least w individuals do;

2. c when i does not contribute and a smaller number than w individuals do;

3. 1 when i contributes and exactly w-1 of the others do;

[3]For convenience, we will some times leave out the subscript.

4. 0 when i contributes and a strictly smaller number than w-1 of the others do.

Individual rationality requires $c_i < 1$ for each individual i's contribution. The following matrix representes these payoffs:

States of the world	**Cont. $\geq$ w**	**Cont. = w-1**	**Cont.< w-1**
Probabilities	p_1	p_2	$1 - p_1 - p_2$
i contributes (C)	1	1	0
i doesn't contribute (NC)	$1 + c$	c	c

In this model, communication is forbidden, players cannot coordinate their strategies; moreover, since the asymmetries between players (their different costs) are private information, they cannot be used as a coordination mechanism. Let's assume that all individuals use the same rule when making their decisions independently and simultaneously. As Palfrey and Rosenthal (1988) prove, whatever beliefs player i may have about the decisions of other players, there is only one strategy which is better, a *cutpoint rule*. A symmetric Bayesian equilibrium is characterized by the critical cost level c^*, the cutpoint, so that contribution is optimal for individual i when $c_i < c^*$ and non-optimal when $c_i > c^*$.

When risk neutrality is assumed, it can be shown that an individual is indifferent about whether he/she contributes or not when his/her endowment c is equal to the probability p_2 that exactly $w-1$ out of the $N-1$ individuals will contribute, i.e. the probability that his/her contribution will make the group reach the threshold required to achieve production of the good. In equilibrium, the probability of an individual contributing is given by $q^* = F(c^*)$, i.e. the probability that his / her cost c is lower than the critical cost c^*. If the individual believes that the others are acting with this probability, then, probability p_2 that his contribution will make the group reach the critical level of provision will be given by the binomial expression to obtain $w-1$ favourable cases out of the $N-1$ possible ones. The set of all the equilibrium points will be given by the set of solutions for c^* in the following equation:

$$c^* = \binom{N-1}{w-1} \left\{ [F(c^*)^{w-1}[1 - F(c^*)]^{N-w} \right\} = p_2 \tag{1}$$

In equilibrium each individual takes p_2 as given when he or she makes a decision, but p_2 is determined endogenously to satisfy equation (1). In fact, in order for c^* to be an equilibrium value, individuals with private value c^* have to be indifferent to contribute or not, $c^* = p_2$. On the other hand, individuals with a valuation less than c^* will not contribute, while individuals with a valuation greater than that value will, so that (1) holds. For instance[4], for $N = 3$, $w = 2$, $\overline{c} = 1.5$, and F the uniform distribution in $[0, 1.5]$, the equilibrium point is calculated by solving the equation (1): $c^* = 2(\frac{c^*}{1.5})[1 - \frac{c^*}{1.5}]$. A solution is $c^* = 0.375$. Since $\overline{c} = 1.5$ this implies that $q^* = 0.25$.

The possibility of multiple solutions for equation (1) is a problem when assessing the experiment results. In this example note that there are two solutions $c^* = 0.375$ and $c^* = 0$. This problem can be avoided by defining the *expectatively stable Bayesian equilibrium (ESE)*. The idea of stability of an equilibrium has to do with the verification of the following convergence process. If everybody started with c_0 as the initial cutpoint, then players could observe how (after certain amount of repetitions) the others would contribute with a probability of $\mathrm{q}_0 = \mathrm{F}(\mathrm{c}_0)$. Thus, the best response for each player would be to adopt a contribution rule where the new cutpoint is given by:

$$c_1 = G(c_0) = \binom{N-1}{w-1} \left\{[F(c_0)^{w-1}[1 - F(c_0)]^{N-w}\right\}$$

Equilibrium c^* is expectatively stable if there is an interval $C(c^*) \subset [0, \overline{c}]$ including c^* such that for all $c_0 \in C(c^*)$, $[c_0 - G(c_0)](c_0 - c^*) > 0$, where $c_0 \neq c^*$. Equilibrium c^* is globally ESE if it is an ESE in the open interval $(0, \overline{c})$. If the parameters N, w and $\overline{c}$ are properly chosen in the experiments, only one global and expectatively stable equilibrium can be obtained. In the example proposed above, only $\mathrm{c}^*= 0.375$ is globally stable. Palfrey and Rosenthal (1991) carry out the experiments with the adecuate parameters N, w and $\overline{c}$, so that there is just one globally stable equilibrium on which the predictions of the Bayesian equilibrium model can be verified. The predictions are:

1. Given c^* for the parameters N, w and $\overline{c}$, individual i contributes if and only if $c_i < c^*$.

[4]This example is in Palfrey and Roshental (1991)

2. The aggregate probability of contribution is given by $q^* = F(c^*)$

The results observed in the experiments differ considerably from the first prediction; many of the individuals do not behave according to this rule. Meanwhile, the second prediction fits the experimental results better, although the observed deviations are still important. In order to explain these deviations, Palfrey and Rosenthal conjecture that individuals act accordingly to biased beliefs and propose the hypothesis that individuals overestimate the probability that the others will contribute (Hypothesis "H").

An interpretation of this hypothesis is that each individual thinks that the rest will act accordingly to some value $c^{**} > c^*$, i.e. their belief concerning the contribution probability of the rest of the group members is higher than the probability determined by the equilibrium point. Due to this belief, they use a cutpoint $c^+ \neq c^*$ which represents their rule of optimal choice.

In order to show how the belief $c^{**} > c^*$ will affect the cutpoint which is actually used, they calculate the derivative $\frac{dc^+}{dq}$ from the equilibrium equation (1), then:

$$\frac{dc^+}{dq} \gtreqless 0 \text{ if } q \lesseqgtr \frac{w-1}{N-1} \tag{2}$$

Let $q^+ = F(c^+)$ denote the actual probability of contribution of an individual, and notice the following resulting predictions when we have $q = q^*$ in equation (2).

1. When $w = 1$, $\quad q^+ < q^*$, i.e., the real probability of contributing to the public good will be less than the one predicted by the equilibrium point.

2. When $w = N$, and $0 < q^* < 1$, $\quad q^+ > q^*$, i.e. the probability observed will be higher than the one predicted by the equilibrium point.

3. When $1 < w < N$ and $0 < q^*$, then $q^+ > q^*$ if $q^* < \frac{w-1}{N-1}$, and $q^+ < q^*$ if $q^* > \frac{w-1}{N-1}$.

As Palfrey and Rosenthal point out, these predictions, which seem to match the data, are not present in alternative models in the literature. Risk aversion can not replicate the prediction of people making contributing some times more and some times less contributions. Even Prospect Theory, which assumes both risk aversion and risk loving in different ranges of preferences make different inconsistency predictions. Private information makes the aplication of predictions of cooperative game theory implausible. Finally, altruistic behavior, as presented in existing models, predicts deviations only in the sense of increasing contributions.

3 A POSSIBLE INTERPRETATION USING REGRET THEORY

Here we present a different approach to the problem at hand using Regret Theory. This is a kind of binary theory, proposed by Loomes and Sudgen (1982, 1987) to explain the paradoxes in Expected Utility Theory. We think that the problem of contributing or not to the achievement of a public good, allows for the existence of a certain degree of regret or satisfaction, depending on whether the individual collaborates or not. This turns out to be important in order to model decision making in this context and Regret Theory enables us to include this kind of psychological feelings.

Whithin this theory, an agent, who is making a choice, does not assess lotteries, but pairs of alternative actions. An action is defined, starting from a finite and exhaustive set of independent states of the world, as a vector $A_i = (x_{i1}, x_{i2}, ...x_{in})$ with state-contingent results. The result x_{ij} is associated to action A_i if state s_j occurs. Every state of the world has a probability p_j which is assumed to be subjectively known.

The central idea of the theory is to incorporate, prior to the valuation of the alternative actions, the individual's future psychological response regarding the final result. This response may be a feeling of regret or shame derived from a mistaken action or, on the contrary, a feeling of joy that comes from having made a correct choice. The choice between two actions A_i and A_k is considered to be a compound experience, in which the choice of one of them means the rejection of the other and so, achieving a certain result, involves losing another one. This may produce a psychological response in the decision maker which he will try to take into account when making his decision.

Take $M_{ij} = M(x_{ij}, x_{kj})$ to be the satisfaction level derived from choosing A_i and rejecting A_k in the state of the world s_j, $M_{kj} = M(x_{kj}, x_{ij})$ is the feeling corresponding to the opposite choice. It is assumed that individuals make their choice in such a way that:

$$A_i \succsim A_k \leftrightarrow \sum_{j=1}^{n} p_j \left(M_{ij} - M_{kj}\right) \geq 0$$

Let $\psi(x_{ij}, x_{kj}) = M_{ij} - M_{kj}$. It is assumed that ψ is an increasing and skewsymmetric function, with $\psi(0) = 0$ and that ψ satisfies a convexity condition called aversion to regret, namely: $\forall a < b < c; \quad \psi(c, a) > \psi(c, b) + \psi(b, a)$.

We now want to apply this theory to the problem of the provision of public binary goods. According to how the problem is stated the individual has to choose between contributing or not. The following matrix corresponds to the payoffs for individual i, the states of the world being associated with the number of contributors different from individual i.

States of the world	**Cont. $\geq$ w**	**Cont. $=$ w-1**	**Cont. $<$ w-1**
Probabilities	p_1	p_2	$1 - p_1 - p_2$
i contributes (C)	1	1	0
i does not contributes (NC)	$1 + c$	c	c

If we apply to this decision problem the valuation rule of Regret Theory for individual i, contributing or not are indifferent actions if:

$$C \sim NC \leftrightarrow p_1\psi(1, 1 + c) + p_2\psi(1, c) + (1 - p_1 - p_2)\psi(0, c) = 0 \tag{3}$$

If we assume that the valuation function ψ depends only on the difference of results, then $C \sim NC \leftrightarrow p_1\psi(-c) + p_2\psi(1 - c) + (1 - p_1 - p_2)\psi(-c) = 0$. If we use the skewsymmetry of the function, then

$$C \sim NC \leftrightarrow p_2 = \frac{\Psi(c^*)}{\Psi(1 - c^*) + \Psi(c^*)}$$

where p_2 is the probability of the world state s_2, i.e., the probability that exactly $w-1$ individuals contribute with c^* as the cutpoint giving us the equilibrium point for function ψ. From here onwards we may find the equilibrium value c^* by knowing the function ψ and solving the equation

$$\frac{\Psi(c^*)}{\Psi(1-c^*)+\Psi(c^*)} = \binom{N-1}{w-1} \left\{ [F(c^*)^{w-1}[1-F(c^*)]^{N-w} \right\} \tag{4}$$

Let us suppose now that all the individuals are equal and use the same valuation function $\psi(x) = x^3$, i.e. they all have the same regret level[5]. Consider the same parameters in the example of Palfrey & Rosenthal, namely, $N = 3, w = 2, \overline{c} = 1.5$ and F being the uniform distribution in $[0, 1.5]$. Take the previously specified utility function. Then equation (4) becomes: $\frac{(c)^3}{(1-c)^3+(c)^3} = \frac{2c}{1.5} - 2(\frac{c}{1.5})^2$ with the solution $c^* = 0.477$, then $q^* = 0.3186$, as in Palfrey and Rosenthal's model the equation (4) has again another solution: $c^* = 0$, which still fails to be globally stable.

Whenever we consider a valuation function ψ being increasing, skewsymmetric and dependent of the differences, we obtain the following results:

(R1) The individual i contributes when and only when his cost c_i is lower than the equilibrium cost c^*.

Proof:

Given $T(c) = \frac{\Psi(c)}{\Psi(1-c)+\Psi(c)}$ we only need to prove that this function $T(c)$ increases in c (see appendix). Since $p_2 = \frac{\Psi(c^*)}{\Psi(1-c^*)+\Psi(c^*)}$ if $c > c^*$, we will have $T(c) > T(c^*) = p_2$ and, therefore, the individual will prefer not to contribute. For $c < c^*$ we will have the opposite situation and the individual will prefer to contribute.

As a result of this, the value c^* will be for this theory a good estimator of the aggregate probability of contribution. Thus, we have the second result:

(R2) The aggregate probability of contributing will be given by $\mathbf{q^* = F(c^*)}$

[5]The function $\psi(x) = x^3$ models in standarized way regret/rejoicing. Other functions having the same characteristics can be used; as we have tried, with $\psi(x) = x^5$, $\psi(x) = x^7$and $\psi(x) = x^9$, the results are very similar. We will leave for further research the estimation of function $\psi(x)$ by means of experimental tests.

Both of these results allow us to assess the experimental results, and see if they are satisfied or not. On an individual level we want to see whether or not individuals with a cost $c < c^*$ collaborate and, if so, how many of them. On an aggregate level we want to determine the proportion of individuals who have contributed, and whether q^* is or not a good estimation. We can also consider whether or not it is possible to add "Hypothesis H" to this theoretical model. We may ask: Will the assumption of biased beliefs predict similar deviations to those produced using the Bayesian equilibrium? It turns out that the answer is affirmative, and the hypothesis of the biased contribution probability will produce a parallel prediction to that of equation (2). If we calculate $\frac{dc^+}{dq}$ in equation (4), for any function ψ (see appendix), we have:

$$\frac{dc^+}{dq} \gtreqless 0 \text{ if } q \lesseqgtr \frac{w-1}{N-1}$$

Recalling that c^+ is the cutpoint or threshold used by individuals in their decision when they act with their biased beliefs, we can conclude that

(R3a) For $w = 1, \quad q^+ < q^*$, there will be a smaller level of contribution than predicted by the theory (Regret Theory).

(R3b) If $w = N$ and $0 < q^* < 1, \quad q^+ > q^*$, there will be a greater level of contribution than predicted by the theory.

(R3c) If $1 < w < N$, $0 < q^*$, then, $q^+ > q^*$ if $q^* < \frac{w-1}{N-1}$ and $q^+ < q^*$ if $q^* > \frac{w-1}{N-1}$, the deviation will depend on the parameter $\bar{c}$.

4 RESULT OF THE EXPERIMENTS: COMPARATIVE STUDY

We undertake now a comparative study of the experimental results obtained by Palfrey and Rosenthal. A total of 33 experiments were carried out with different parameters and in different centres during 1984, 1987 and 1988[6]. The amount of data is

[6]We acknowledge the contribution of Professor Palfrey and Professor Rosenthal. They offered us the use of the data which was obtained in the experiments to be analysed.

sufficient for statistical conclusions. The experiments were divided into three types depending on the parameters which were established, so that both the predictions of the Bayesian theory and the predictions of the same theory together with hypothesis H could be assessed. We will call type 1 experiments those carried out with parameters $w = 1$ and $N = 3$. In this case it is expected, as we have seen, that the contribution will be lower than the one predicted by the theory. Type 2 experiments will be those carried out with parameters $w = 3$ and $N = 3$, so that it is required that everybody contributes in order to provide the public project. It is expected that the contribution will be above the one predicted by the theory. Finally, type 3 experiments are those carried out or with $w = 2$ and $N = 3$ or $w = 2$ and $N = 4$. The prediction in the latter type of experiments goes in one direction or the other, depending on the value of $\overline{c}$.

Within each type of experiments, changes of parameter $\overline{c}$ were carried out. As stated above, a total of 33 experiments were performed, and 12 individuals took part in each one (except in experiments of type 3, where the number of participants was 9). Each experiment lasted, in general, for 20 periods. In each period the participants were assigned at random to different groups and without their knowledge of which group they were assigned to[7].

[7] See Palfrey & Rosenthal (1991) for more details about the experiment.

Type 1 experiments

$\mathbf{w = 1}$	$\mathbf{N = 3}$ Actual contribution	Bayesian cont.	Regret cont.	B. group cont.	R. group cont.
2.25	0.217	0.192	0.179	0.250	0.234
	0.213	0.192	0.179	"	"
1.50	0.311	0.306	0.308	0.313	0.324
	$0.221^{b,r}$	0.271	0.279	"	"
	0.263	0.271	0.279	"	"
	0.333^{b}	0.271	0.279	"	"
	0.292	0.269	0.278	"	"
0.750	0.379^{r}	0.392	0.504	0.431	0.529
	0.404^{r}	0.392	0.508	"	"

($\overline{c}$ is the label of the first column.)

The data in the second and third columns, called Bayesian and Regret Theory contribution respectively, are the theoretical contribution frequencies for the Bayesian equilibrium with risk neutrality and for the Regret Theory with $\psi(x) = x^3$. Frequencies are calculated by using the valuations which were taken in each experiment and so, if an individual had a cost below the equilibrium point, the theory predicts contribution. The last two columns are the aggregate contribution probabilities for either theories. Here, we calculate the equilibrium point c^* and, by means of this point, the global contribution frequency, since the distribution probability is uniform in $[0, \overline{c}]$. The piece of information in the corresponding box is $q^* = F(c^*) = \frac{c^*}{\overline{c}}$. It is clear that this number is constant for all the experiments with the same parameters. A superscript (^{b}) shows a deviation of the theoretical frequency (in this case the Bayesian one), which is significant in a level of 5% on the basis of a z-test, using normal approximation to the binomial. The superscript (^{r}) corresponds to the same concept in Regret Theory.

If we include now the Hypothesis H in this type of experiments, it is expected that the individuals contribution is lower than that predicted by the theory. It is worth to notice that in experiments with significant deviations from Regret Theory, all of those deviations are lower than that predicted by the theory according to Hypothesis H. Regarding Bayesian Theory, in one of the experiments the deviation goes in the opposite direction to that predicted by hypothesis H. If we look at the last two columns which provide the aggregate contribution probabilities for both theories, all the results satisfy Hypothesis H (the probabilities observed are always lower than the theoretical ones).

Type 2 experiments

w = 3 **N = 3**

$\overline{c}$	**Actual Contribution**	**Bayesian cont.**	**Regret cont.**	**B. group cont.**	**R. group cont.**
2.25	0.096^r	0	0.062	0	0.058
	0.129^r	0	0.062	0	"
1.50	0.311^r	0	0.158	0	0.145
	0.196^r	0	0.133	"	"
	0.250^r	0	0.133	"	"
0.995	0.440	0	0.420	0	0.337
0.750	0.525	0	0.562	0	0.606
	0.596	0	0.600	"	"

In these experiments it is noteworthy that the only Bayesian equilibrium is $c^* = 0$ and, therefore, this theory predicts a theoretical probability of zero contribution. Evidently the deviation compared to the data observed is always significant for any statistical test. Although it is true that the data is always consistent with Hypothesis H, the hypothesis always implies for these parameters that the participation will be above the theoretical one. Bayesian Theory does not provide any information.

Regret Theory offers much more information in these experiments. Furthermore, for those cases where the deviations are significant, at a 5% level, if we add Hypothesis H, the contribution frequencies observed are always higher than that predicted (column 3), in keeping with H.

Type 3 experiments

w = 2 **N = 3**

$\overline{c}$	**Actual contribution**	**Bayesian cont.**	**Regret cont.**	**B. group cont.**	**R. group cont.**
2.25	0.192^{b}	0	0.196	0	0.193
	$0.159^{b,r}$	0	0.196	0	"
1.50	0.394^{b}	0.222	0.361	0.250	0.319
	0.350^{b}	0.239	0.289	"	"
	$0.383^{b,r}$	0.244	0.277	"	"
	0.308^{b}	0.238	0.289	"	"
	0.308^{b}	0.238	0.275	"	"
	$0.363^{b,r}$	0.238	0.287	"	"
	$0.379^{b,r}$	0.238	0.283	"	"
0.750	$0.521^{b,r}$	0.596	0.621	0.624	0.647
	0.558^{r}	0.596	0.621	"	"
0.667	$0.580^{b,r}$	0.674	0.700	0.667	0.706

In these experiments, except for one, Bayesian Theory provides predictions which are always deviated at a significant level of 5%. In this case the deviation above or below the theoretical prediction depends on the parameters used, if we assume Hypothesis H. For $\overline{c} = 2.25$, $\overline{c} = 1.50$, since q^{*} is less than $\frac{w-1}{N-1} = 0.5$ (fourth and fifth columns), the contribution frequency observed has to be higher than that predicted by the theories. On the contrary, for $\overline{c} = 0.750$, $\overline{c} = 0.667$, since $q^{*} > 0.5$, the deviation will go in the opposite direction.

For Regret Theory if we look at the experiments where the deviation is significant, it only goes in the opposite direction to that predicted by H for the case where $\overline{c} = 2.25$. Let us, finally, analyse the data from the experiments with $w = 2$ and N = 4.

w = 2	**N = 4**				
	Actual	**Bayesian**	**Regret**	**B. group**	**R. group**
$\overline{c}$	**contribution**	**cont.**	**cont.**	**cont.**	**cont.**
2.25	$0.309^{b,r}$	0.132	0.206	0.134	0.205
	$0.221^{b,r}$	0.104	0.167	"	"
	0.200^{b}	0.104	0.167	"	"
0.667	0.550^{r}	0.523	0.627	0.529	0.624

For these parameters, in case $\overline{c} = 2.25$, we have $\frac{w-1}{N-1} = \frac{1}{3}$. Thus, since $q^* < \frac{1}{3}$, Hypothesis H implies that the contribution probability will increase with respect to the theoretical prediction, whereas for the case $\overline{c} = 0.667$, since $q^* > \frac{1}{3}$, then the frequency observed will be lower. We can say for this case that both theories perform similarly, sincethe estimation is a good fit for the data of three experiments, while in the three others the prediction deviates from the theoretical results. For both theories, if Hypothesis H is added, we can guarantee that the deviations are produced in the predicted direction.

It is worth to notice that in all the experiments performed, except for those of type 1 corresponding to the parameters $N = 3$, $w = 1$, $\overline{c} = 2.25$, the cutpoint given by Regret Theory is larger than the one given by Bayesian Theory. Clearly, by choosing conveniently the parameters we can guarantee this result. This fact yields some predictions which fit the experimental data better than Bayesian Theory. Nevertheless, the effect is a bigger contribution in all cases. Unfortunately, the data indicate that contributions are some times over and some times above the ones predicted by Regret Theory. This makes Hypothesis H necessary to explain the direction of deviations. We could say that the possible regret generated by not contributing, together with the overestimation of the probability of the rest of the people contributing, gives a good explanation of the experimental data.

5 CONCLUSIONS

We have analysed the data of a considerable number of experiments that simulate the problem of the provision of binary public goods, and have used an alternative theory to interpret the results, Regret Theory. The advantages of using this theory are twofold. On the one hand, the corresponding analysis avoids using the Expected Utility Hyphothesis, an underlying assumption of Bayesian Theory. Although the use of Regret Theory is technically more complicated than Bayesian Theory, we have shown that it provides us with a valid alternative. On the other hand, Regret Theory enables us to take into account different psychological features other than risk aversion, considerations which are certainly important when tackling this problem.

Hypothesis H, which is introduced to explain the direction of the deviations, does so surprisingly well. For Bayesian Theory, the deviations observed with respect to those predicted by the theory go in the direction implied by Hypothesis H in all of the experiments except six of them. We find just one experiment where the deviation of the results of the predictions of Regret Theory, on a statistically significant level, goes in the opposite direction to that predicted by Hypothesis H. For Bayesian Theory, it has to be taken into account that, in the cases of unanimity, any contribution percentage is consistent with Hyphothesis H. This is not the case for Regret Theory, which also provides in this particular case the participation percentages as in the other experiments.

Some important aspects are left for a subsequent study. It would be useful to evaluate Hypothesis H. We can ask, for example: Is it possible to estimate how many individuals overestimate the others member's contribution probability? Can this be related to the number of altruistic individuals? Also, due to the fact that in order to apply Regret Theory to this problem we have assumed that all individuals express the same amount of regret/rejoice through only one valuation function, it would be important to estimate by means of an experiment the valuation function reflecting the level of common regret assumed in this analysis.

The problem of the provision of public goods still lacks a final solution. Although mechanisms have been found which ease the problem, it remains to find the solution.

We consider this study to present a different and new approach to this area of study. Although there is still a long way to go, we think that this new approach can, at least, throw more light on the problem. We will continue to work in this direction.

APPENDIX

1. Function $T(c)=\frac{\psi(c)}{\psi(c)+\psi(1-c)}$ increases in c for any ψ increasing function.

The derivate $T'(c)=\frac{\psi'(c)[\psi(c)+\psi(1-c)]-\psi(c)[\psi'(c)-\psi'(1-c)]}{[\psi(c)+\psi(1-c)]^2}=$
$=\frac{\psi'(c)\psi(1-c)+\psi(c)\psi'(1-c)}{[\psi(c)+\psi(1-c)]^2}\geq 0 \quad \forall c.$

2. Given $\frac{\psi(c)}{\psi(c)+\psi(1-c)}=\binom{N-1}{w-1}\left[F(c)^{w-1}(1-F(c))^{N-w}\right]$ with $F(c)=q$,then we have $\frac{dc^+}{dq}\gtreqqless 0 \leftrightarrow q\lesseqqgtr\frac{w-1}{N-1}$.

Solving implicitly in the equation:
$\frac{\psi(c)}{\psi(c)+\psi(1-c)}-\binom{N-1}{w-1}\left[q^{w-1}(1-q)^{N-w}\right]=0.$

We have:

$$\frac{dc}{dq}=-\frac{\binom{N-1}{w-1}\left[(w-1)q^{w-2}(1-q)^{N-w}-(N-w)q^{w-1}(1-q)^{N-w-1}\right]}{\frac{\psi'(c)[\psi(c)+\psi(1-c)]-\psi(c)[\psi'(c)-\psi'(1-c)]}{[\psi(c)+\psi(1-c)]^2}}=$$

$$=\frac{\binom{N-1}{w-1}\left[(w-1)q^{w-2}(1-q)^{N-w}-(N-w)q^{w-1}(1-q)^{N-w-1}\right]}{\frac{\psi'(c)\psi(1-c)+\psi(c)\psi'(1-c)}{[\psi(c)+\psi(1-c)]^2}}$$ since the denominator is always positive, we have:

$$\frac{dc^+}{dq}\gtreqqless 0 \leftrightarrow \left[(w-1)q^{w-2}(1-q)^{N-w}-(N-w)q^{w-1}(1-q)^{N-w-1}\right]\gtreqqless 0$$

$$\leftrightarrow (w-1)(1-q)-q(N-w)\gtreqqless 0 \leftrightarrow w-1\gtreqqless q(N-1)$$

$$\leftrightarrow q\lesseqqgtr\frac{w-1}{N-1}$$

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